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13-V-1889.

A. M. CAMPBELL

Presidential Address.

BY

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10-2-1907 U.S.A.

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PROCEEDINGS
OF
THE CANADIAN INSTITUTE.

PRESIDENTIAL ADDRESS. BY B. E. WALKER, ESQ., F.G.S.

(Read 12th November, 1898.)

The scientific student, or even the mere student of science, a quite different thing, by the way, should be one who seeks truth for its own sake, indifferent to the effect it may have on his preconceptions. If we turn to the last century, we find those who were interested in the physical history of the earth readily adopting the speculations of such men as Buffon and Werner, and so captivated by their plausible theories, based on little observation, that men like Guettard and Demarest, industrious observers who gathered facts before they ventured to theorize, were utterly disregarded, although their methods and conclusions were purely scientific in spirit and have helped to build the body of real truth which was so lamentably retarded by their brilliant contemporaries. Practically the spirit of original research and of open-mindedness in accepting the results of the researches of others, is of modern origin, and such liberty of observation and thought is even yet looked upon by some as a dangerous use of our faculties. There are still those who regard the modern spirit of enquiry as an attack upon whatever old foundations may seem to constitute orthodoxy in either religion or science. But this modern spirit of scientific study covers much beside the observation of truths connected merely with the physical and natural world around us. It covers practically all knowledge which may be systematized. It is that state of mind toward all phenomena which, if we were perfectly free from bias, would not permit us to vary any conclusion warranted by the facts, in favour of our preconceived ideas or beliefs. Of course very few, if any, can entirely escape the baneful effect of preconceptions, and it is to be feared that men of science are sometimes as dogmatic and prejudiced as others. Too many follow a quest in science which may not be truth, perhaps a quest of material gain, or of mere intellectual enlargement, by adding to the facts which sustain a theory already held. The scientific student should rise above all other considerations to the moral altitude of mere truth for its own sake. If it is a truth which he is unable to square with other truths, he should be willing that it should remain a disturbing anomaly until time shall have solved it. Let us, however, descend from these high levels into the so-called practical affairs of life.

There are those who question the importance of any new fact in the natural or physical world unless the material good to flow from it to man is apparent. What is the use of studying plants, or insects, or other inedible animals, or fossils? What is the use of Crookes's tube, they would have said a few years ago? And there are those of higher intelligence who although willing to admit the value of studies bearing on the origin of life, on evolution or some recognized philosophy, still question the wisdom of spending long years in the discovery of

facts which have no clear connection with other established items of knowledge. Many among the so-called practical men of the world realize the value of the entomologist who can do something to check the ravages of insects injurious to vegetation, the botanist who understands problems of forestry, or who with the added knowledge of the chemist knows the food or the medicinal value of plants, the geologist who happens to discover a coal or a gold mine, the biologist who actually saves human life by his knowledge of bacteria, or who by his knowledge of their habits shows how the fish supply of the world may be increased. But they do not always understand that the scientific discoverers who are thus able to do some direct good to man would not in all probability have attained such knowledge had they attacked the unknown fields of science in any other spirit than that which recognizes that all newly discovered items of fact are infinitely valuable, whether we can at the moment put them to any direct use or not.

No one is wise enough to recognize the full value of a newly-discovered fact. One new fact may seem to have nothing to recommend it, except its anomalous character. Another may seem of enormous importance. But some later discovery may change all this, disclosing the value of the apparently anomalous fact and diminishing the value of that which seemed the most important. Our duty is to treasure every new truth or fact discovered, no matter how unimportant it may appear. We can readily understand that what seems now of trifling value may be intimately connected with the working out of some problem in which man is deeply interested.

This may seem an unnecessarily elaborate manner in which to draw your attention to the claims of palæontology, the subject in which I hope to interest you to-night. In its early history it was peculiarly a study in which patience was necessary in recording facts which seemed to have little more than mere stratigraphical value to the discoverers. And even now that it may claim to be a body of systematized knowledge, its value is certainly underestimated in this centre of colleges and universities.

The simplest manner in which to judge of the value of any particular branch of science, such as palæontology, is doubtless to consider its interdependence with other branches of science. In the ultimate analysis, of course, all science is interdependent, but I refer to that interdependence which at once occurs to the student who desires to be a specialist. The entomologist soon finds that he must know something of botany, the botanist that he must know something of entomology. Both soon learn, also, that without some knowledge of geology, if only of soils and altitudes, they cannot proceed very far.

Let us, then, first consider the value of palæontology to the student who is trying to work out the physical history of the globe. In the record of fossils he finds almost his only sure guide. If he tries to work backward through the crust of the earth, beginning with the most recent conditions on the surface, he finds that there is but one satisfactory guide proving the regular succession of the different strata of rocks, and this is palæontology. If he concludes that the stratigraphical arrangement of the sedimentary rocks is for practical purposes the most satisfactory measure of time, he must also conclude that without the palæontological record there could be no system of stratigraphy, and that where the stratigraphic sequence is broken there is little beside the correlation of the fauna in the two unconformable strata from which to measure the time represented by the break in the sequence. It may be well to recount very briefly how our present knowledge of stratigraphy has been gained and the extent to which this knowledge is due to palæontology. The first attempt to systematize the rocks comprising the crust of the earth was made by the Freiburg professor of mineralogy, Werner.⁽¹⁾

(1) Many of the references to individual geologists have been taken from Sir Archibald Geikie's "Founders of Geology."

He advanced the theory that the globe was once completely enveloped in water—that is, that the water was high enough to cover the highest mountain. From and in this water the rocks forming the basis of everything were chemically precipitated. These, according to Werner, included granite, gneiss, mica-slate, clay-slate, serpentine, basalt, porphyry and syenite. He even asserted at first that the chemical deposition was made in the order in which the rocks are here arranged. These were his Primitive rocks, and they were followed by what he termed Transition rocks, some of which were of chemical deposition and some sedimentary. Then came the so-called Floetz rocks, partly chemical, but in the main sedimentary. It became necessary, however, to recognize the existence of volcanoes, and he taught an eager, listening world that volcanoes were the result of the burning up of seams of coal and other inflammable sediments; and that volcanic action was one of the most recent of physical forces at work in the earth. If ever there was an instance of the value of collecting facts, no matter how apparently dissociated from each other, until a system could be built which would defy attack, we have it in the Neptunist geology of Werner. He could not wait for facts, but theorized most brilliantly on the basis alone of what could be gathered in the mining district in which he lived. He contended that basalt was not volcanic, and satisfied most people, after a violent controversy, that it was not, and that obsidian and pumice were chemically deposited in water, while at the same time in France the patient, tireless investigator, Demarest, who refused to theorize, had laid before a world quite deaf to facts, the truth, as now recognized, regarding basalt and the real basis of what we know regarding volcanoes.

It is true that the great founder of accurate geology, Hutton, did not upset the theories of Werner and others by the aid of fossils, but he established forever the value of ascertained facts, of real evidence as opposed to theory. He laid down the great principle in geology, that we must judge of the action of the earth in the past by the action we see around us in the present. The doctrine of Uniformity in its extreme form is, of course, disputed by many,⁽¹⁾ but the main principle as here stated is generally accepted. Hutton thus settled, in many cases for all time, the manner in which the sedimentary rocks were created, setting aside the absurd notion of Werner's ocean depositing, chemically and by sediments, layers on the sloping sides of mountains covered to their tops by the sea. Hutton not only understood correctly the forces creating rocks but the destructive forces of erosion and the creation of watersheds and river systems.

But although both Werner and Hutton knew that the various rocks were created in succession and that in this succession there was an order which it was desirable to understand, other men laid the real foundations of palæontology in its relation to stratigraphy. As early as 1779 the Abbé Giraud-Soulavie, in France, set forth in a paper a stratigraphical description of a district in France in which the different strata were arranged by him in relation to their fossil contents, and in which he demonstrated that in the older rocks the fossils had no similar living species, while in some of the later rocks a percentage of the fossils were identical, or nearly related to living species. Little attention, however, was paid to these important truths, and his systematic arrangement of the rocks in question is not now recognized. The Abbé was followed by two great Frenchmen whom the world was obliged to regard. Cuvier and Brongniart were biologists who realized that they could not disregard the biological relations of fossils to living forms. Indeed, we owe it to Cuvier that palæontology is accorded its place in the study of biology, while Brongniart, in his zoology of the Trilobites, thus early demonstrated to what extent even an extinct tribe of crustaceans may be systematized and accorded their place in the order of natural history. But at the moment we

(1) Lord Kelvin "Popular Lectures and Addresses," vol. II., page 6. Prestwich's Geology, 1886, vol. I., page 2.

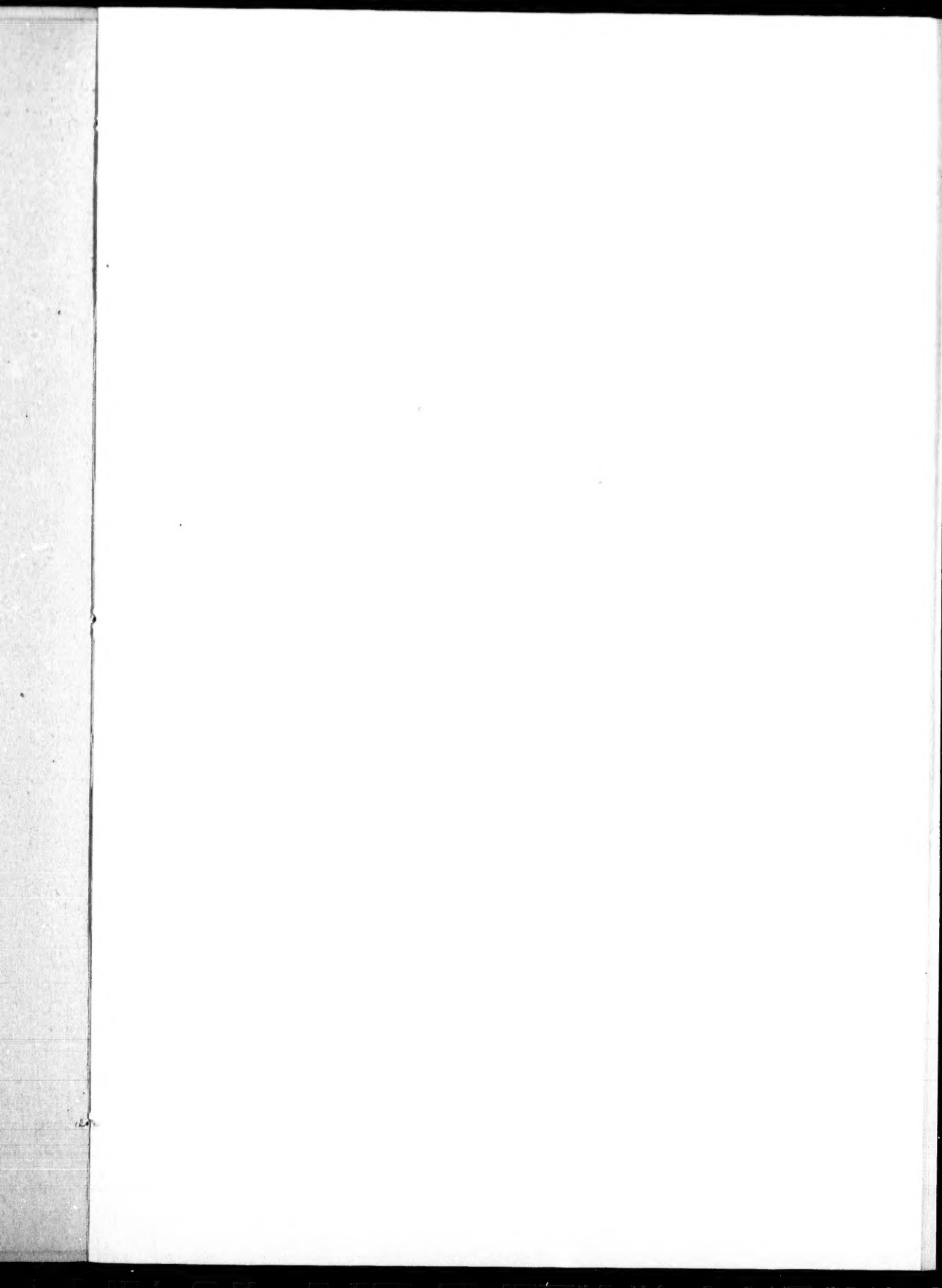
are concerned only regarding their contributions to stratigraphy. Working together, these two great men thoroughly studied the geology and palæontology of the Paris basin, and established the systematic arrangement of the Tertiary or Kainozoic formations so firmly that although many new minor divisions have been added, few alterations have been made, and the main features of the present classification are as they arranged them. They distinctly state that they based their classification and division of the rocks upon the fact that at the same horizon in a series of rocks, even when examined in widely separated places, they found that the groups of fossils were generally alike. Their conclusions, which in the complete form reached the public in 1808, were followed in 1813 by the results of the labours of another Frenchman, D'Omalius d'Halloy, who worked out with true stratigraphical principles the Secondary or Mesozoic rocks of France.

Turning now to the development of stratigraphy in England, as early as 1760 the Rev. John Michell had stated most intelligently the principles of the stratification of rocks, but he contributed nothing towards the nomenclature of a system. English stratigraphy practically began with the well-known William Smith. He was born in the same year with Cuvier, and outlived him seven years, but, instead of the splendidly endowed biologist, we have only a land surveyor, imperfectly educated. He drew up as early as 1799, although he did not publish it beyond distributing copies by hand among a few scientific friends, a card of the English strata, with a tabular list of formations from the Coal up to the Chalk, giving the thickness of the several members, lists of the fossils peculiar to each, and the lithological changes. In 1815 he published a geological map covering all England, of which all subsequent maps are practically but an elaboration, and he established the Jurassic system as permanently in England, besides much of our knowledge of the Secondary rocks, as Cuvier and Brongniart did the Tertiary in France. The geology of the Secondary or Mesozoic rocks in England as known to-day is filled with the names of formations given by Smith, and we owe to him the first sufficient arrangement of the Primary or Palæozoic and the Secondary or Mesozoic rocks from the Old Red Sandstone to the Chalk. So that he and the Frenchmen referred to cleared up on palæontological grounds the entire stratigraphy from the Old Red Sandstone to the present time.

Practically nothing was known in 1831 of the stratigraphy of the rocks below the Old Red Sandstone, and I have only now to refer to the splendid work of Murchison and Sedgwick in establishing as the result of investigation in England, Wales, Scotland, the Alps and elsewhere, the Cambrian, Silurian and Devonian systems; and of the subsequent investigations, still being pursued, to work out the pre-Cambrian rocks, the foundation efforts in which are now by common consent accredited to our own great geologist, Sir William Logan, whose portrait hangs upon our walls as the first President of this Institute. Sir Archibald Geikie, on whom I have drawn most liberally for personal facts regarding the early geologists, says:—(1) "The determination of the value of fossils as chronological documents, has done more than any other discovery to change the character and accelerate the progress of geological inquiry."

The geographical discoverer is unsatisfied as long as there is a shore line not marked upon the map of the world, and naturally the geologist is unsatisfied as long as there is a section in his geological column the nature of which he has not determined. We have shown how the geological column from the top or present time back to the base of the Cambrian has been determined satisfactorily by the aid of palæontology, and we have suggested the value of such a complete record to the student trying to work out the physical history of the globe. But the geological column extends below the Cambrian to the Archæan, representing a period of time regarding the measure of which the geologist, the biologist, and

(1) Sir Archibald Geikie, "The Founders of Geology," page 242.



the physicist are in most thorough disagreement. Are there no more fossils below the base of the Cambrian to illumine this dark period? In the Lower Cambrian of North America, according to Mr. Walcott, one of the leading authorities on the Cambrian time, there are as many as 160 species, and these cover all classes of marine invertebrates. Clearly, then, in the Lower Cambrian we are not near the beginning of life on this planet, and surely we are not near the earliest preserved remnants of life.

The rocks in North America which are older than the Cambrian are divided by Dr. Dawson⁽¹⁾ in descending order, as follows:—

1. Keweenawan.

2. Animikie.

Here throughout a great part of North America, there occurs a profound unconformity.

3. Huronian.

4. Upper Laurentian or Grenville Series.

5. Lower Laurentian or Fundamental Gneiss.

It is evident that if fossils are found in any of these groups the Palaeozoic division must be extended downward to include such groups and the Archæan division be that much diminished. A problem, then, of enormous importance awaits solution by the geologist. How much further down than the recognized Lower Cambrian will he be able to carry the record of fossil forms? In the present state of our knowledge we find vast areas of these older rocks which seem to be sedimentary, but which appear to contain no fossils, vast areas regarding which we are not sure whether they were sedimentary or not, and again vast areas which we believe we have proved never to have been sedimentary. About this confused period floods of argument have been written and many hypotheses advanced, but what we want are fossils. Fortunately we have a few, although they do not help us very materially. Mr. G. F. Matthew, who constitutes our main authority in Canada on the subject, considered palæontologically, has established as pre-Cambrian, *br.* Palæozoic, beds in New Brunswick and Newfoundland which he calls Etcheminian,⁽²⁾ and which Sir William Dawson thinks to be equivalent to the Keweenawan.⁽³⁾ They contain "but a meagre fauna, mostly animals . . . a low type of structure, as Protozoans, Brachiopods, Echinoderms, and Molluscs," with worm-burrows and trails. Mr. Walcott, in a memoir on the Lower Cambrian,⁽⁴⁾ writes as follows:—

"The section laid bare in the Grand Cañon of the Colorado, beneath the great unconformity at the base of the known Cambrian, shows 12,000 feet of unaltered sandstones, shales, and limestones, that, I think, were deposited in pre-Cambrian time and should be referred to the Algonkian (Keweenawan). The entire section of pre-Cambrian strata is unbroken, and the sandstones, shales, and limestones are much like those of the Ordovician section of New York. In a bed of dark argillaceous shale, 3,500 feet from the summit of the section, I found a small Patelloid or Discinoid shell, a fragment of what appears to be the pleural lobe of a segment of a trilobite, and an obscure, small Hyolithes, in a layer of bituminous limestone. In layers of limestone, still lower in the section, an obscure Stromatoporoid form occurs in abundance. These fossils indicate a fauna, but do not tell us what it is." In the same memoir, in a note at the foot of page 552, Mr. Walcott mentions the discovery of *Salterella* and fragments of a trilobite, 500 feet below a series of beds in Vermont which are 700 feet thick, of conformably bedded lime-

(1) G. M. Dawson. Presidential Address, Geological Section, B.A.A.S., 1897.

(2) G. F. Matthew. The Protolenus Fauna, Trans. N.Y. Acad. Science, vol. xiv., page 105, 1895.

(3) Sir W. Dawson. Note on Cryptozoön and other Ancient Fossils, Can. Record Science, vol. vii., page 203, Oct. 1896.

(4) C. D. Walcott. The Fauna of the Lower Cambrian, etc., U.S. Gov't Surv. Annual Report, page 550, 1888-9.

stone, and lie beneath the *Olenellus* Zone (the so-called base of the Cambrian). In the pre-Cambrian rocks of Wales and elsewhere fossils have been found, but not of a more satisfactory character than those already mentioned. I do not here discuss the so-called fossils of the Huronian and Laurentian, because until the vast beds of the Keweenawan and Animikie are cleared up it is hardly worth while to enter upon a mere controversy as to whether certain forms are fossils or not.

The subject is complicated by the many breaks or unconformities in Cambrian and pre-Cambrian times. In the extended areas of ancient rocks in North America there are sections where the Lower or some younger portion of the Cambrian rests directly upon Archæan or other pre-Cambrian rocks, and there are places where the section is conformable from the Cambrian series downward for many thousands of feet into the Keweenawan. Therefore, considering the many widely separated sections in North America, if at any point downward we were able to say we had reached the stage where in North America the Palæozoic rocks ended, it would seem at first sight as if we might conclude that the fossil remains found at this base, represented the beginning at least of organisms having hard parts. But presuming that the labours of Matthew, Walcott, and others eventually carry the Palæozoic record through the Keweenawan, down to the lowest of the beds of the Animikie, which "except when of volcanic origin," resemble "in their aspect the older Palæozoic sediments," we are then met, at least in the areas which Dr. Dawson has so happily called the "continental Protaxis of the North," with a gap in the record which he describes in the address from which I have already quoted, as "the vast lapse of time, constituting probably one of the most important breaks in geological history, by which the Cambrian and its allied rocks are separated from those of the Huronian and Laurentian systems." Regarding this break, Dr. Dawson says: "It would be difficult to deny that the time thus occupied may not have been equal in duration to that represented by the whole of the Palæozoic."

In the scattered and unsatisfactory fragments referred to above it cannot be said that we have found a fauna essentially different from the Cambrian, but somewhere—it may be in North America, in the Salt Range of India, in the Torridon sandstones of Scotland which are pre-Cambrian and said to be 10,000 feet in thickness, in Bohemia or Wales—we will doubtless be able to carry the history of the highly-developed trilobites and other organisms of the Cambrian at least further back towards their origin. This is the undiscovered shoreline in geology. In quest of it the Nansens of geology will travel as long as the limits of discovery are unsolved. We must not, however, forget that animals without hard parts leave no, or nearly no, record, and that the progenitors of many animals with hard parts had themselves no hard parts. In this connection Professor Marr,⁽¹⁾ after discussing the peculiarities of a well-known Cambrian trilobite, says: "If this be so, the entire outer covering of the trilobites, at a period not very remote from the end of pre-Cambrian times, may have been membranous, and the same thing may have occurred with the structures analogous to the hard parts of organisms of other groups. Indeed, with our present views as to development, we can scarcely suppose that organisms acquired hard parts at a very early period of their existence, and fauna after fauna may have occupied the globe, and disappeared, leaving no trace of its existence."

I have thus far been considering the value of fossils in demonstrating the position and relative age of the different strata of the earth's crust. It is not necessary for such purposes that the fauna of one stratum should bear any likeness to that of an immediately older or younger stratum. Indeed, to some extent,

(1) J. E. Marr. Presidential Address, Geological Section, B.A.A.S., 1896.

the less alike the better for mere purposes of distinguishing strata. It was, therefore, not unnatural that the early geologists, believing, as they did, that each particular animal or plant was a special effort of creation, should fail to recognize the value of biology in connection with the study of fossil remains. Indeed, when Cuvier and Brongniart, and, later, Deshayes and Lyell, undertook to correlate the organisms in the later rocks with living organisms—to point out where they were identical, where they were related but not identical, and where there seemed little relation—there were not wanting those who doubted the value of biology in the study of geology, and who persisted in estimating the value of fossils merely as guides in the stratigraphical arrangement of the rocks. Comparatively few fossils had been gathered, specific differences were often not recognized, the doctrine of evolution had not been advanced, and as I have already said, any particular fossil might be regarded as an organism whose history had no relation to anything but itself. The change which has come about in fifty or sixty years would be incredible were the record not clearly before us. I am not able to state even approximately the number of species now known, but a few detached facts will sufficiently illustrate the scope of modern palaeontology. Prestwich estimated the species found in Great Britain in the Palaeozoic rocks at 5,697, in the Mesozoic rocks at 7,546, and in the Kainozoic, including the Quaternary, at 4,013. That is, altogether, at 17,256 species, in the British Isles. This, as we know, is but a trifling part of the earth's area, although it is that which has been most thoroughly examined. Berrande estimated the Silurian species alone of Europe and America at 10,674, to which, of course, many have been added since the calculation was made. Every year great numbers of new forms are described and new territory is put under examination. No one would be so foolish as to attempt to guess the number of species which will eventually be recorded in science. If one will turn from the meagre text-books of the first half of this century to Zittel's⁽¹⁾ five large volumes, in which the first effort is made at a complete classification of all branches of palaeontology, he will realize that the natural history of fossil animals is scarcely less perfect in its system of classification, or in its range of information, than the natural history of living animals. But it will be urged that after all we have only the hard parts of animals preserved. The soft parts are gone, and, worse still, the animals which had no hard parts have left almost no trace at all. This is quite true, and at first sight it seems an inestimable loss to the student of evolution. How will he ever fill the gaps in his record if only the bones have been preserved for him?

In the case of fossil animals having apparently no living analogues, had there been no theory of evolution there would doubtless have been no great desire to ascertain the nature of the soft parts, and thus to establish them in their proper places in the systems of natural history. And certainly in many cases, where the analogy is now clear, without this interest on the part of the biologist it would not have been suspected. But if in some class of fossil animals there are still a few living analogues, it is wonderful to what a degree the generic relations can be worked out and a system, satisfactory even to the biologist, be created, which shall include all the known extinct and living forms, even when the fossil species outnumber the living by a hundred to one. Allow me to illustrate this point by reference to the work done in connection with one of the most, if not the most, ancient order of shells, the brachiopoda. About 1884 Dr. Thomas Davidson, after thirty years of labour on the subject, finished the first great work on brachiopods⁽²⁾. It fills five quarto volumes and is illustrated by 250 plates. What is perhaps more striking is the fact that the bibliography which completes the work, consists of 160 quarto pages, containing the titles of over 2,500 publications dealing with brachio-

(1) Karl von Zittel. *Handbuch der Palaeontologie*, 5 vols., 1876-1893.

(2) T. Davidson. *British Fossil Brachiopoda*, 2a, vol. I.-VI., Publications of Palaeontographical Society, 1890-1895.

pods. The brachiopod is a bivalve, but with valves of unequal size. In the overwhelming majority of cases in the fossil form the valves are found united, and, as the valves are filled either with sediment or with crystallized matter, the interior is rarely visible. This involved a greater difficulty than that of merely ascertaining the marks of the attachments of the organs on the inner sides of the shells. The brachiopods have supports for the soft parts, the so-called arms, in the shape of loops or spirals, or other processes, and while in modern brachiopods these are not calcareous, in fossil forms they were. These spiral and other processes were occasionally but rarely exposed and separated valves showing the muscular markings were also found, but naturally the first attempts at systematizing the brachiopods were largely based on mere external characters. During the progress of Dr. Davidson's labours, however, the Rev. Norman Glass, assisted him materially. By the exercise of great ingenuity and delicate workmanship he removed the shells and exposed the delicate brachial supports referred to, in the case of many species, so that a greatly improved system was the result. It is but right to say that others were working upon the brachiopods in the same direction, notably Mr. Whitfield, of the American Museum of Natural History, New York. The number of known fossil species has, however, kept on increasing at a surprising rate, and we have also added largely to the known living forms. Dr. Davidson's work was, therefore, soon followed by important contributions from D. P. Oehlert, in 1887,⁽¹⁾ and by Professor Zittel in his Hand-book, already referred to. It was still maintained that we possessed no treatise in which "facts in regard to structure, function, habits, and distribution of these animals, the distinguishing characters and systematic relations of their genera," are included in one work. This Professor Hall and his co-workers have sought to do in the "Introduction to the Study of the Brachiopoda" and in the eighth volume of the Palaeontology of New York. Here we can readily follow their history from the very minute and rudimentary brachiopods in the Lower Cambrian through their enormous development in the Palaeozoic both in numbers of individuals and in variety of form and size, continuing in lessened though still great numbers through the Mesozoic, and gradually lessening until the present age, of which Professor Hall records only 147 species, many of which are mere varietal forms. Whether we consider the shapes of the valves as they have been influenced by the soft parts which are now gone, the microscopic structure of the shells, the systems of defence by spines, imitative surface markings or otherwise, the infinitely varied and very beautiful processes for supporting the arms, the muscular scars, the complicated nature of the hinge, the foramen, the evidence as to fixity of habit or the reverse, or any other feature which may leave its morphological evidence on the fossil; or the softer parts which may be seen in living forms and by the aid of which both the structure and habits of the fossil organisms may at least to some extent be understood, we must admit that the history of the Brachiopoda, as gathered from the study of both fossil and living forms has produced a result infinitely more satisfactory to the biologist and the geologist than could have been possible by the study of the fossil forms alone by the old-fashioned geologist and of the living forms alone by the old-fashioned biologist. And he would be a foolish man who undertook to say whether the fossil or the living forms had most aided in the final result. Both are absolutely necessary.

In almost any other branch of fossil remains quite as valuable evidence of the growth of palaeontology on its biological side might be adduced. In the Protozoans, George Jennings Hinde by his microscopic work is carrying the evidence of the existence of Radiolarian remains farther and farther back in the Palaeozoic rocks, and Messrs. W. D. and G. F. Matthew have found Globigerinidae in phos-

(1) Paul Fischer. Manuel de Conchyliologie, Paris, 1887, with an appendix on the Brachiopods by D. P. Oehlert.

phatic nodules in the Cambrian rocks of New Brunswick.⁽¹⁾ In the Sponges Mr. Hinde has done splendid work,⁽²⁾ while Dr. Hermann Rauff has been some years labouring upon a systematic arrangement of all the known fossil forms.⁽³⁾ Professor H. A. Nicholson has made the first attempt at systematizing our knowledge of those difficult Hydrozoans, the Stromatoporoids,⁽⁴⁾ and Professor Lapworth and several other investigators are doing similar work upon the almost equally difficult Hydrozoans known as Graptolites. In the Actinozoans a vast quantity of work has been done on fossil corals since the epoch-making volumes of Milne-Edwards and Jules Haime, but the great work of revision has not been undertaken as yet. In the Echinoderms, the camerate crinoids have been revised in a most elaborate manner by Messrs. Wachsmuth and Springer,⁽⁵⁾ and work of perhaps a higher character is now being done by Mr. F. A. Bather,⁽⁶⁾ of the British Museum. In the Crustaceans there have been monumental works such as Barrande's, but such important discoveries as those of Beecher and others in demonstrating the morphology of the underside of the trilobites, so long practically unknown, and the wealth of forms and knowledge of embryology and zonal conditions made known by the researches of Walcott and G. F. Matthew in the Cambrian will make a general revision necessary sooner or later. In the Molluscs, in addition to the Brachiopods, a great deal has been done by Professor H. A. Nicholson,⁽⁷⁾ E. O. Ulrich,⁽⁸⁾ G. B. Simpson,⁽⁹⁾ and others, in the Palæozoic Polyzoans or Bryozoans, both towards increasing our knowledge of forms and in systematizing our knowledge, although there is not enough agreement as yet for the comfort of the ordinary student. In the Molluscs good work is being done in every direction, notably in this country, in Mesozoic forms, by Mr. Whiteaves, of our Survey, but the time has perhaps not come for a general revision of any of the classes unless it may be the Cephalopoda. These have, throughout the history of palæontology, attracted great attention, but perhaps the work of Hyatt and of Zittel, based on palæo-biological lines, has been the most important from our own point of view. However, so many men of ability have devoted themselves to the Jurassic ammonites alone, that one is afraid to venture upon an opinion as to the probability of general agreement in a scheme of classification. In connection with vertebrate palæontology, it is not necessary to speak, as the names of Cuvier, Agassiz, Owen, and Cope, among those who have passed away, are well known to you all, and many distinguished workers remain who will continue to fill the gaps, making the vertebrate record more and more complete as the years roll by.

If I had time I should like to discuss the value of that kind of palæontological study, as it is now being carried on by certain investigators, in which regard is had to the stratigraphical relations of certain fossils on the one hand, and their biological relations on the other, in order to demonstrate their evolution. In the Quarterly Journal of the Geological Society of London,⁽¹⁰⁾ for August last, Mr. S. S. Buckman has divided the entire Jurassic system into minute zones, each zone

(1) G. F. Mathew. The Protolenus Fauna, Trans. N.Y. Acad. Science, vol. xiv., page 109, 1895.

(2) G. J. Hinde. British Fossil Sponges. Publication of Palæontographical Society, 1886-1893.

(3) H. Rauff. Palæospongiologie, Memoir in Palæontographica, edited by Prof. K. A. von Zittel, Stuttgart, 1893.

(4) H. A. Nicholson. British Stromatoporoids. Publications of Palæontographical Society, 1885-1892.

(5) Wachsmuth and Springer. North American Crinidea Camerata, Memoir, Mus. Comp. Zool., Harvard, 1897.

(6) F. A. Bather. As an example of Mr. Bather's Palæontological work, see *Petalocrinus*, Q.J.G.S., vol. liv., pages 401-441.

(7) H. A. Nicholson. The Genus *Menticulipora*, Blackwood, Edinburgh, 1881.

(8) E. O. Ulrich. Geological Surv. Illinois, vol. 8, 1890. Geological Surv. Minnesota, vol. 3, 1895.

(9) G. B. Simpson. Different Genera of Fenestellidae, 13th Annual Report N.Y. State Geologists, 1894. Hand-book, N. A. Palæozoic Bryozoa, 48th Annual Report, N.Y.S. Mus. and 14th Annual Report N.Y.S. Geologist, 1895.

(10) On the grouping of some divisions of so-called "Jurassic" Time, S. S. Buckman, Q.J.G.S., vol. liv., pages 442-462, August 1898.

based upon a species of ammonite; and by the use of these zones in determining the precise age of one species relatively to another, he has been able to produce the genealogical tree of the Jurassic ammonites in a manner which should be satisfactory to the evolutionist. Doubtless this attempt to divide up the geological formations into zones named from apparently dominant species and to work out with this aid the phylogeny of families or orders may be carried too far. Clearly, however, by being able to divide the formations on biological grounds, so as to establish with reasonable precision the relative moment when a particular species arrived and flourished, and by being able to study young and mature individuals of the species so as to work out its embryology, great progress is being made in the history of the development of species through the medium of fossils.

I feel that I owe the members of the Institute an apology for the character of my address. My business duties preclude the possibility of engaging in original investigation even if I possessed ability of that kind. I have, therefore, merely sought by an address of a popular character to engage your attention regarding a branch of study which has been a source of deep interest to myself for many years.

